

Utility of crankshaft clips for middle cerebral artery aneurysms: A single-center experience of 150 cases

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Abstract

Background: Applying more than one clip for a complicated-shaped aneurysm is an established strategy, particularly for middle cerebral arteries (MCA). However, obliterating the cleft of the internal elastic lamina with a single clip is theoretically possible because the line is usually on a single plane. Crankshaft clips were reformed for that purpose decades ago, but are not widely used and have been described in almost no report ever since.

Methods: To reconsider and describe the utility of crankshaft clips for complicated MCA aneurysms and to articulate the advantages and limitations of the clips, we meticulously analyzed a series of more than 150 cases in which the crankshaft clips were used, predominantly for treatment of MCA aneurysms, at Moriyama Memorial Hospital between August 2010 and December 2015.

Results: Readjustment of the clip was not necessary in almost all cases, and the first application was the final one. None of the patients had morbidity or mortality related to the surgical technique. To date, we have not experienced any trouble or recurrence.

Conclusions: Crankshaft clips are useful and safe for clipping of complicated MCA aneurysms.

Key Words: Crankshaft clip, closure line, middle cerebral aneurysm, multiple clipping

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INTRODUCTION

Despite the recent undeniable success of endovascular obliteration of intracranial aneurysms,^[4,8,17] clipping remains the only method that can provide a complete cure of the disease.^[5,22,23] For a complete cure, the separated internal elastic lamina should be closed as completely as possible.^[15] Both *de novo* aneurysm and regrowth of a previously clipped aneurysm can potentially lead to subarachnoid hemorrhage.^[3,9] However, the

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orifice of intracranial aneurysms is often a complicated, three-dimensional structure and difficult to completely obliterate. In order to decrease the potential for regrowth of an aneurysm, clipping at the ideal closure line is recommended. This ideal closure line of an aneurysm, defined as the line emerging at clipping, is a relatively new concept, first described by Ishikawa in 2007.^[10,11] To make an ideal closure line, clipping with multiple clips has been widely used,^[1,12,20,21] however, limitations on the approach angle and working space prevent some aneurysm clips from achieving an ideal closure line, in particular, for aneurysms in deep locations.

Meanwhile, crankshaft clips were created by modifying a bayonet clip to occlude the thin wall or reddish bleb of the neck close to the parent artery.^[14,19] This technique was referred to as “shank clipping” by Osawa *et al.*^[19] We started to use these clips for complicated middle cerebral artery (MCA) aneurysms since the development of the Sugita 2 clips.^[24] More than 150 crankshaft clips have been used in the last 6 years in our institute alone, 96% of which were for MCA aneurysms.

Here, we describe our experience using crankshaft clips at Moriyama Memorial Hospital between August 2010 and December 2015.

MATERIALS AND METHODS

Since 2010, advanced versions of 3 newly designed bayonet clips have become available from Elgiloy as Sugita 2 clips (crankshaft clips; manufactured by Mizuho Ikakogyo Co. Ltd., Tokyo, Japan) [Figure 1].^[24] The most remarkable changes from the previously available clips were the opening widths (C01, from 5 to 9 mm; C02, from 6 to 10 mm; C03, from 6.5 to

10 mm) [Figure 1].^[24] YASARGIL crankshaft clips (Aesculap AG & Co., Tuttlingen, Germany) have also been available since the commencement of the second-generation cobalt alloy clips.^[2] The numbers of clips used in this series are following: C01 41, C02 55, and C03 26 for Sugita 2 clips, FT770T 8, FT771T 8, and FT772T 12 for YASARGIL clips.

The primary difference between the former clips and the newer titanium clips is the constituent. Therefore, in terms of the opening width of the crankshaft clips, Sugita clips are more advantageous. The purpose of the crankshaft clip is to occlude the thin wall or reddish bleb with its shank portion because these parts are the most likely future origin of bleeding, and therefore, should be closed completely. Mizuho reported a graph showing the comparison between closing force and depth of Sugita clips in their official site.^[24] Fortunately, the closing force of the clip is the strongest at its coil part [Figure 2],^[24] allowing for firm occlusion of the thin wall to prevent future rupture.

We examined a series of 150 cases in which crankshaft clips were used at Moriyama Memorial Hospital between August 2010 and December 2015. Of the 150 cases, 146 (96%) were MCA aneurysms, and of the remaining 6, there were 4 anterior communicating artery (ACOM) aneurysms, 1 basilar top aneurysm, and 1 distal anterior cerebral artery (ACA) aneurysm. Forty percent of the aneurysms ruptured and 70% of them occurred in women. Only cases with aneurysmal size <10 mm were included.

Ishikawa *et al.* described 3 different types of aneurysm configurations,^[10,11] the most common of which is the bifurcation type, which stems from a curved linear cleft originating at the bifurcation of the arteries.^[11] The other two types, the trunk and combined type, are not suitable for clipping with a crankshaft clip.^[11]

For our cohort, final confirmation of the bifurcation type was done after meticulous exposure of the

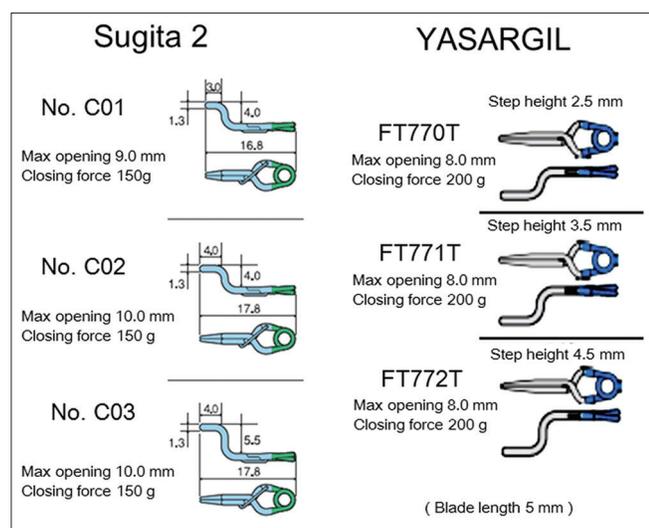


Figure 1: Commercially available crankshaft clips. Sugita 2 clip (left). YASARGIL clip (right). The figure is modified from their catalogs. All the numbers are in millimeter (mm)

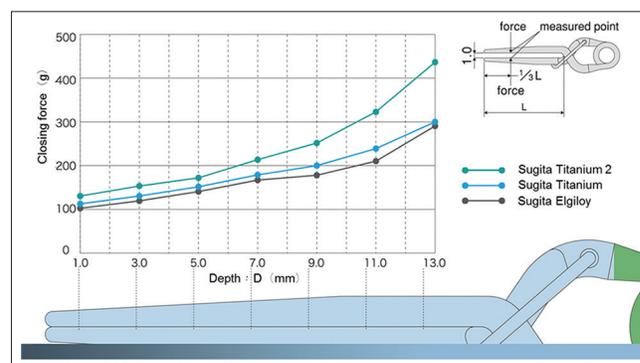


Figure 2: The graph shows that the closing forces of the Sugita clips gradually becomes larger as it closes to its coil part. The characteristic are consistent in Sugita titanium 2, Sugita titanium, and Sugita Elgiloy clips

aneurysm and parent arteries. Rupture did not occur in most cases; therefore, temporary clipping or adenosine administration, used for ruptured cases only,^[16] was not used. Ideal closure lines were made by selecting the ideal size of the clip and pulling the stable part of the dome [Figure 3]. Indocyanine green (ICG) angiography was used for all cases to confirm complete clipping.^[7]

RESULTS

More than 150 crankshaft clips were used, predominantly for MCA aneurysms. We achieved an ideal closure line with the crankshaft clip in all cases. Two types of MCA aneurysms were closed using crankshaft clips. First, which dominated the series, has a main round dome with a thin-wall bleb [Figure 4]. For those cases, the shank portion of the clip was used to obliterate the fragile bleb with stronger closing forces [Figures 2 and 4]. The other cases contained wide and flat domes that were homogeneously reddish and fragile [Figures 5 and 6]. For this type of aneurysm, multiple clipping seemed extremely risky and, therefore, crankshaft clipping was the best choice.

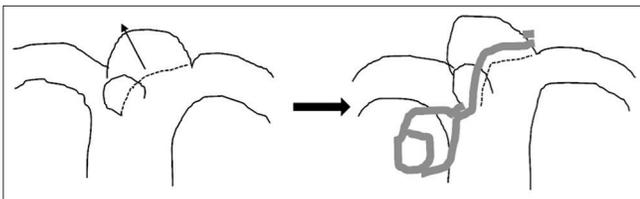


Figure 3: Illustrations showing how to make an ideal closure line with a crankshaft clip. Usually, the angle of closure line is an obtuse angle (left). Gently pulling its dome makes the angle closer to a right angle and the crankshaft clip fits the closure line

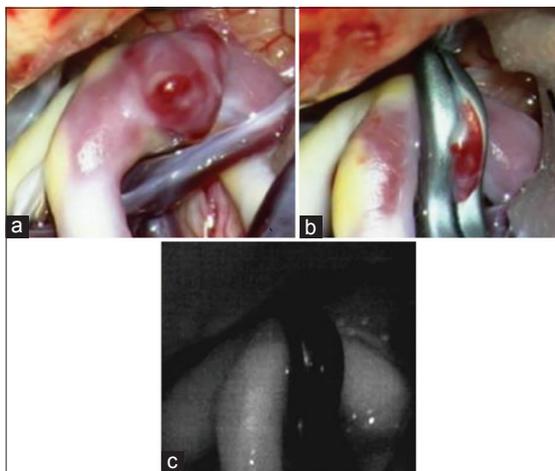


Figure 5: Illustrative case 2. (a-c) intraoperative pictures. (a) A clearly exposed right middle cerebral artery aneurysm which had widened, flat, fragile dome. (b) A crankshaft clip was nicely applied. (c) Indocyanine Green angiography shows a complete clipping and patency of its parent arteries

The clip that most used was the medium-sized Sugita 2 clip (C02). This clip has a 4 mm blade and a 4 mm shank portion and fits in most cases to make an ideal closure line [Figures 4 and 5]. The other two Sugita 2 types were also used in many cases depending on the aneurysm size. YASARGIL clips were used less often, but the longest one (FT772T) was useful in the case of a longer closure line [Figure 6]. Readjustment of the clip was not necessary in all cases and the first application was the final one. None of the patients had morbidity or mortality related to the surgical technique.

DISCUSSION

Despite the recent dramatic improvement in endovascular treatment,^[4,8,17] clipping surgery is still indispensable for MCA aneurysms owing to the complicated structure of the aneurysms,^[5,22,23] and multiple clipping is a well-accepted treatment strategy.^[1,12,20,21] The bifurcation

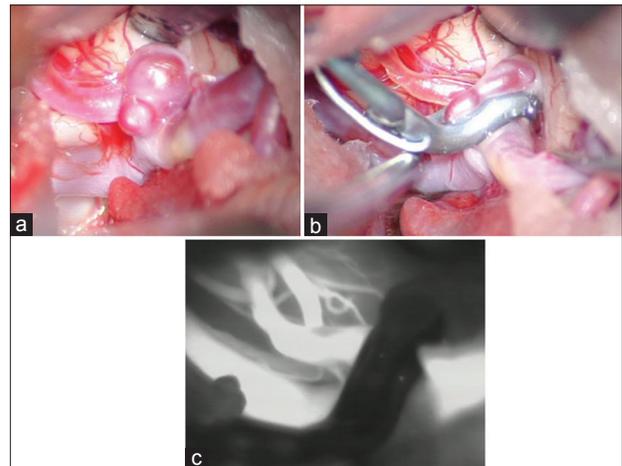


Figure 4: Illustrative case 1. (a-c) intraoperative pictures. (a) A clearly exposed right middle cerebral artery aneurysm with a bleb in front of it and its parent arteries. (b) A crankshaft clip was nicely applied. (c) Indocyanine Green angiography shows a complete clipping and patency of its parent arteries

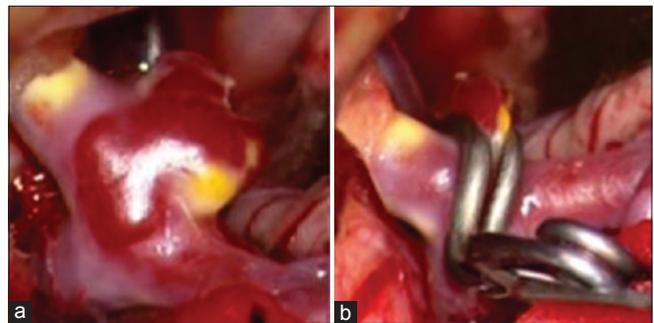


Figure 6: Illustrative case 3. (a, b) intraoperative pictures. (a) A clearly exposed right middle cerebral artery aneurysm and its parent arteries. (b) A crankshaft clip (YASARGIL) completely obliterated the large, widened, flat aneurysm

type of MCA aneurysm has a deeply curved closure line, which requires additional clips for the dog-ear remnant part.^[10,11] In such cases, bipolar coagulation^[13,18] and combination clip techniques^[1,12,20,21] can be considered. However, bipolar coagulation may cause premature rupture, and multiple clipping techniques use tandem clipping or fenestrated clips and are rather complex. The technique we used here, called “shank clipping,” was first reported for complicated MCA aneurysms in 1995.^[19] The idea originated from the fact that, in almost all these cases, the angle formed between the two clips was 90°.^[19] Although shank clipping is not as widely accepted as multiple clipping, because the shape of the shank portion does not always match the shape of the aneurysm neck,^[11] we re-used this technique recently because of its simplicity, reliability, and cost-effectiveness. We were able to overcome this shape limitation in unruptured cases by pulling the stable part of the dome, which changes the neck shape close to the crank shape [Figure 3]. While 6 crankshaft clips are available,^[2,24] choosing the right one is critical for complete obliteration. Sugita 2 clips have wider opening width and are easier to handle.^[24] YASARGIL clips have longer blades and stronger closing forces,^[2] and are therefore preferable for large-sized aneurysms.

Multiple clipping has been a widely used technique for complicated MCA aneurysms because the ideal closure line can be achieved with it.^[1,12,20,21] However, it is a more complicated technique and requires more experience. Reapplication of the first clip is often necessary, which might cause premature rupture. In addition, the very small dog ear tends to slip away from the clip as it is closed and a second clip application is not always ideal, particularly when the dog ear is so thin that the clip may avulse the very thin portion of the wall that it holds. For more complex cases of red, flat, and wide dome aneurysms, reapplication or multiple clipping should be avoided and obliterating the entire neck in one attempt is ideal; therefore, these are the best candidates for crankshaft clips. Moreover, if a single clip can make the ideal closure line, there is less risk of error.

Another advantage of the crankshaft clipping compared to multiple clipping is its continuity. Regardless of how close the clips are, there still is a cleft of internal elastic lamina from which a recurrence can originate. Closing the closure line without discontinuity gives patients the best opportunity for ultimate cure of the aneurysm. Because the shank portion of the crankshaft clip has a stronger closing force, it is ideal for obliterating a fragile bleb. The closing forces of Sugita 2 clips are 150 g, measured at one-third point from the tip, however, those at the shank portion of the clips are estimated at more than 200 g because the force increases closer to its coil part.^[24] Closing forces of the YASARGIL crankshaft clips are greater.^[2]

While crankshaft clipping is not feasible in the case of a large, atherosclerotic aneurysm, here we used the clip for large-sized (almost 10 mm) MCA aneurysms in a couple of cases. However, a single crankshaft clip was not strong enough to close the long, hard neck, and an additional “booster clip” was necessary. The “picket fence” clipping technique is a recently reported method for clipping large, atherosclerotic aneurysms using a number of parallel straight clips;^[6] however, the idea of reconstructing the neck with the tips of many straight clips along the neck is opposite to that of this single crankshaft clipping.

One of the limitations of using a single crankshaft clipping is that it requires wide space because the operator should face the closure line perpendicularly for a complete obliteration. Therefore, it is useful for aneurysms located in a wider location such as MCA aneurysms in which the aneurysmal neck often includes the arterial junction. They are also useful for some ACOM aneurysms if enough space is available. In our series, the crankshaft clips were used for aneurysms in locations other than the MCA in only six cases.

SUMMARY

Crankshaft clips are useful and safe for clipping of complicated MCA aneurysms. We could make ideal closure lines with the clips by using a couple of tips. This could be an alternative method of multiple clipping technique.

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Conflicts of interest

There are no conflicts of interest.

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